

METHODS AND SYSTEMS FOR PROVIDING MOBILE LOCATION
MANAGEMENT SERVICES IN A NETWORK ROUTING NODE

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Description

METHODS AND SYSTEMS FOR PROVIDING MOBILE LOCATION MANAGEMENT SERVICES IN A NETWORK ROUTING NODE

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Technical Field

The present invention relates to methods and systems for providing location management functionality in a wireless communications network. More particularly, the present invention relates to methods and systems for providing location management services in a network routing node, such as a signaling system 7 (SS7) signal transfer point (STP) or and Internet protocol (IP) enabled SS7 signaling gateway (SG).

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Background Art

Within the wireless telecommunications industry, the current trend in network technology is divided between global system for mobile communications (GSM) and American National Standards Institute – 41 (ANSI-41) based architectures. In many respects, GSM and ANSI-41 based networks are quite similar, with the primary differences between the two technologies relating to the protocols used to communicate between the various network entities and the operating frequencies of the communication handsets. In the near future, next generation network architectures, such as Universal Mobile Telecommunications Systems (UMTS) and General Packet

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Radio Service (GPRS), will likely provide the network infrastructure for large-scale wireless communications around the world. As such, even though the description herein relates primarily to GSM networks, it is understood that the present invention applies to other types of mobile communications networks, including ANSI-41, Personal Communication Services (PCS), UMTS, and GPRS networks.

A simplified GSM network architecture is illustrated in Figure 1. As shown in Figure 1, the exemplary GSM network environment includes a home network, generally indicated by reference numeral **100**, and a visited network, generally indicated by the numeral **110**. As used herein, the term “home network” is used to refer to the network in which an HLR storing the mobile subscriber is location and subscription information resides. The term “visited network” refers to the network in which a mobile subscriber is roaming. Home network **100** presented in Figure 1 includes a home location register (HLR) **104** and a gateway mobile switching center (GMSC) **106**. Similarly, visited network **110** includes a GMSC **112**, a first mobile switching center (MSC) **114** and associated visitor location register (VLR) **116**, and a second MSC **120** and associated VLR **122**. Also illustrated in Figure 1 are a pair of base station system (BSS) units **118** and **124**, which are associated with MSC **114** and MSC **120**, respectively.

An HLR is a database, used to store subscriber information for a particular GSM service provider's subscribers. Functionally, an HLR is linked through a signaling network to other service areas such that subscriber information may be efficiently shared between geographically diverse networks. This sharing of information facilitates seamless intra- and inter-

network roaming. A VLR, like an HLR, is also a database that contains mobile subscriber information. However, a typical VLR is closely associated (and often co-located) with a specific MSC and stores information related to mobile subscribers currently being served by that MSC.

5 Again, the network elements described above (HLRs and VLRs) can be thought of as essentially databases or database processing nodes. Unlike these database nodes, MSCs and GMSCs are generally identified as network switching elements that support or process both signaling and bearer (e.g., voice) type traffic. Among their many functions, MSCs and GMSCs are
10 responsible for determining which cell site will take possession of a call. Such handoff control is facilitated by a communication link between an MSC and an associated BSS. A GMSC may also provide connectivity to one or more foreign or remote networks; otherwise, MSC and GMSC functionality is very similar.

15 When a mobile subscriber roams within the coverage areas of different MSC nodes, standard GSM network location updating procedures are employed to keep the mobile subscriber's HLR informed of the current location of the mobile subscriber. For example, as mobile subscriber **126** shown in Figure 1 roams from the service area associated with MSC **114** to
20 that of MSC **120**, a number of signaling messages are generated by and communicated between MSC **114**, VLR **116**, MSC **120**, VLR **122**, GMSC **112**, GMSC **106**, and HLR **104**. Again, the goal of such signaling activity is to provide the mobile subscriber's HLR with the information necessary to locate the roaming mobile subscriber within a home or visited network, and to
25 provide the VLR with the information necessary to complete calls to the

roaming subscriber. A detailed discussion of such location or call management signaling operations can be found in *The GSM System for Mobile Communications* by Michel Mouly and Marie-Bernadette Pautet, Cell & Sys 1992.

5 Figure 2 is an exemplary signaling message flow diagram associated with a typical location update operation triggered by roaming mobile subscriber **126** shown in Figure 1. When mobile subscriber **126** roams into the coverage area served by MSC **120**, mobile subscriber **126** registers with MSC **120** (line 1), which triggers a location update transaction. VLR **122**
10 generates a signaling system 7 (SS7) mobile application part (MAP) *UpdateLocation* signaling message, which is routed to the mobile subscriber's HLR **104** (line 2). The *UpdateLocation* message includes information identifying the new serving MSC and VLR (MSC **120** and VLR **122**). The mobile subscriber's HLR **104** receives and processes the
15 *UpdateLocation* message and, in response, sends the serving VLR information related to the roaming mobile subscriber **126** (line 3). This mobile subscriber information is conveyed to VLR **122** in a MAP *InsertSubscriberData* signaling message. VLR **122** receives and processes the *InsertSubscriberData* message and responds to HLR **104** with an
20 *InsertSubscriberData_Ack* message (line 4). The location updating transaction is concluded when HLR **104** sends an *UpdateLocation_Ack* message to VLR **122** (line 5). HLR **104** informs former serving VLR **116** that mobile subscriber **126** has roamed into a new MSC/VLR service area. Consequently, the mobile subscriber's information may be deleted from the
25 former serving VLR database. In a GSM network, such instructions are

communicated to a VLR via a MAP *CancelLocation* signaling message. In Line 7, VLR 116 acknowledges that the location information has been deleted with a *CancelLocation_Ack* message.

In the network architecture described above, no information is shared between VLR nodes within the same visited network. As a result, each time a mobile subscriber roams from one serving MSC/VLR to another within the same network, a number of signaling messages must be routed back to the mobile subscriber's home network to access the mobile subscriber's HLR data. As the number of mobile subscribers increases and the amount of inter-network roaming increases, the inefficiency and costs associated with such an architecture become significant. Furthermore, there is presently a great deal of interest in so-called "micro-cell" wireless network architectures. Micro-cell wireless network architectures include a large number of relatively small base stations and MSC nodes, as opposed to current architectures, which employ a relatively small number of large base stations and MSC nodes. In such micro-cell architectures, MSC/VLR (or MSC/VLR functional equivalent) service areas may be greatly reduced in size. As a result, the frequency of roaming between MSC/VLR service areas may be significantly increased, along with the frequency of location updating type transactions in the network.

In response to the location updating issues described above, various entities in the wireless communication industry have proposed a solution known as a gateway location register (GLR). A detailed discussion of GLR functionality can be found in *3rd Generation Partnership Project; Technical Specification Group Core Network; Gateway Location Register (GLR) –*

Stage 2 (Release 1999), 3G TS 23.119 v3.0.0 (2000-03), the disclosure of which is incorporated herein by reference in its entirety.

The above-referenced industry standards publication describes a GLR entity that receives and processes certain signaling messages in a mobile network. A GLR entity, as described, provides temporary local storage for subscriber information associated with non-home mobile subscribers roaming in the wireless network served by the GLR entity. That is, a GLR entity requests, receives, and temporarily caches information associated with a roaming mobile subscriber. The GLR entity distributes this information to VLR nodes in the local network as required. In essence, a GLR entity behaves in a manner similar to a VLR during transactions with an HLR and in a manner similar to an HLR during transactions with a local VLR.

While in theory such GLR functionality has the potential to significantly optimize location updating type transaction processing across network boundaries, the above-referenced industry standards publication does not address problems associated with implementing such an entity in a mobile communications network. For example, adding a stand-alone GLR node to an existing wireless network would require an SS7 point code to be allocated for the GLR node. However, point codes are becoming a scarce and consequently valuable commodity. Also, many network operators do not wish to deploy new point codes unless absolutely necessary because it involves re-provisioning of other network nodes, and there are usually regulatory fees involved. Furthermore, SS7 routing rules within other nodes in the wireless network would also require modification to reflect the addition of the new GLR node to the network. From a network operations standpoint,

the administration of a new GLR network element would also entail a significant amount of effort and cost. Therefore, there exists a long-felt need for a cost-effective, efficient solution to the location management problems of conventional mobile communications networks.

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Disclosure of the Invention

According to one aspect, the present invention includes a mobility management routing (MMR) node that efficiently performs both location management signaling operations associated with mobile subscribers and signaling message routing functionality typically provided by a network routing node, such as a signaling system 7 (SS7) signal transfer point (STP) or an SS7-over-Internet protocol signaling gateway (SG). The MMR node includes a communication module capable of transmitting and receiving signaling data packets over a network, as well as one or more databases that provide both home location register (HLR) and visitor location register (VLR) functionality. More particularly, the MMR node receives and caches HLR data, which is subsequently distributed to other nodes in the network as requested or needed. The MMR node also receives and temporarily caches VLR data, which is subsequently utilized as required. An MMR node may provide such functionality by intercepting mobile query and response signaling messages. That is, an MMR node may intercept, examine, and process certain signaling messages that are not explicitly addressed to a network address associated with the MMR node. Alternatively, an MMR may receive and process certain mobile signaling messages addressed to a network address that has been assigned to the MMR node.

Accordingly, it is an object of the present invention to provide a signaling message routing node that provides gateway location register (GLR) functionality, in addition to routing functionality, in a wireless communications network.

5 It is another object of the present invention to provide a signaling message routing node that can intercept, terminate and respond to certain mobile signaling messages that are used to communicate mobile subscriber location information between a visitor location register and a home location register.

10 It is another object of the present invention to decrease inter-network signaling message traffic associated with mobile subscriber location management.

 It is another object of the present invention to provide a signal transfer point-like network element that includes an integrated GLR processor.

15 It is another object of the present invention to provide a signal transfer point (STP) or STP-like network routing element that includes an integrated GLR processor where the GLR processor and the STP share the same network point code.

 It is another object of the present invention to provide a system and
20 method for deploying GLR functionality in a wireless communications network without requiring the modification or re-programming of signaling message routing rules in other elements in the network.

 Some of the objects of the invention having been stated hereinabove, other objects will become evident as the description proceeds, when taken in
25 connection with the accompanying drawings as best described hereinbelow.

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Brief Description of the Drawings

Figure 1 is a network diagram illustrating a conventional mobile telecommunications network architecture and associated network elements.

5 Figure 2 is a message flow diagram illustrating an exemplary location management transaction involving several mobile telecommunications network elements.

Figure 3 is a schematic diagram of a conventional signaling gateway (SG) routing node suitable for use with embodiments of the present invention.

10 Figure 4 is a block diagram illustrating an exemplary internal architecture of an MMR node according to an embodiment of the present invention.

15 Figure 5 is a network diagram illustrating an exemplary implementation of an MMR node in a mobile communications networking environment according to an embodiment of the present invention.

Figure 6 is message flow diagram illustrating an exemplary initial *UpdateLocation* transaction involving an MMR node according to an embodiment of the present invention.

20 Figure 7 is a message flow diagram illustrating an exemplary subsequent *UpdateLocation* transaction involving an MMR node according to an embodiment of the present invention.

Figure 8 is a network diagram illustrating an exemplary *CancelLocation* transaction involving an MMR node according to an embodiment of the present invention.

Figure 9 is a message flow diagram illustrating an exemplary *CancelLocation* transaction involving an MMR node according to an embodiment of the present invention.

Figure 10 is a message flow diagram illustrating an exemplary
5 ProvideRoamingNumber transaction performed by an MMR node according to an embodiment of the present invention.

Detailed Description of the Invention

Disclosed herein are several embodiments of the present invention,
10 which may include an underlying hardware architecture similar to that of a telecommunications network packet routing switch, such as a signal transfer point (STP) or a signaling gateway (SG) routing node. As used herein, the term "signaling gateway" refers to a packet routing node capable of routing call signaling messages between nodes of different protocols, such as
15 signaling system 7 (SS7) nodes and IP-based signaling nodes (e.g., signaling nodes that communicate via SUA/M2UA/M3UA/SCTP, SIP/SDP, TALI, GPRS, etc.). An exemplary base architecture suitable for use with embodiments of the present invention includes the EAGLE® STP and the IP⁷
™ Secure Gateway, both available from Tekelec of Calabasas, California.
20 Figure 3 is a block diagram of a signaling gateway architecture suitable for use with embodiments of the present invention. In Figure 3, signaling gateway **250** includes the following subsystems: a maintenance and administration subsystem (MAS) **252**, a communication subsystem **254** and an application subsystem **256**. MAS **252** provides maintenance
25 communications, program load, peripheral services, alarm processing and

system disks. Communication subsystem **254** includes an interprocessor message transport (IMT) bus that is the main communication bus among all subsystems in the IP⁷™ Secure Gateway **250**. This high-speed communications system may include two 1 Gbps counter-rotating serial buses.

Application subsystem **256** includes application cards capable of communicating with the other cards through the IMT buses. Numerous types of application cards can be incorporated into SG **250**, including: a link interface module (LIM) **258** that provides SS7 links and X.25 links, an data communication module (DCM) **260** that provides a TCP/IP interface to an IP network, and an translation service module (TSM) **262** that provides global title translation, gateway screening and other translation services. A database service module (DSM) **264** may also be provided to support number portability service.

Mobility Management Routing Node Internal Architecture

Figure 4 illustrates a mobility management routing (MMR) node according to an embodiment of the present invention. In Figure 4, MMR **300** includes an interprocessor message transport (IMT) bus **304** that is the main communication bus among internal subsystems within MMR **300**. In one embodiment, this high-speed communications system includes two 1 Gbps counter-rotating serial buses. A number of distributed processing modules or cards may be coupled to IMT bus **340**. In Figure 4, these cards include: a pair of maintenance and administration subsystem processors (MASPs) **306**, an SS7 capable link Interface module (LIM) **308**, an Internet protocol (IP) capable

data communication module (DCM) **330**, and a location caching module (LCM) **340**. These modules are physically connected to IMT bus **304** such that signaling and other types of messages may be routed internally between active cards or modules. For simplicity of illustration, only single LIM, DCM, and LCM cards are included in Figure 4. However, MMR node **300** may include multiple LIM, DCM, LCM and other cards, all of which may be simultaneously connected to and communicating via IMT bus **304**.

MASP pair **306** provides maintenance communications, initial program load, peripheral services, alarm processing and system disks. Because MASP pair **306** is not particularly relevant to a discussion of MMR functionality, a detailed discussion of the design and operation of MASP pair **306** is not provided herein.

Focusing now on LIM card functionality, in the illustrated embodiment LIM **308** is comprised of a number of sub-components including: an SS7 MTP level 1 and 2 module **310**, an I/O buffer or queue **312**, an SS7 MTP level 3 layer discrimination module **314**, and a distribution module **316**. MTP level 1 and 2 module **310** includes hardware and software for sending and receiving digital data over a particular physical medium. MTP level 1 and 2 module may also provide error detection, error correction and sequenced delivery of SS7 message packets. I/O queue **312** provides for temporary buffering of incoming and outgoing signaling message packets. MTP level 3 discrimination module **314** performs a discrimination function, effectively determining whether an incoming SS7 message packet requires internal processing or is simply to be through switched, i.e., routed to another node.

In one embodiment, discrimination module **314** examines a service indicator

octet (SIO) value in the received message packet in order to determine whether internal signaling connection control part (SCCP) processing is required. Distribution module **316** handles the internal routing of SS7 message packets that require additional processing prior to final routing.

- 5 DCM **330** shown in Figure 4, includes an SS7/IP converter **332** and an I/O queue **334**. Outgoing SS7 message packets routed through the DCM **330** will be transmitted out of MMR node **300** and into an Internet protocol (IP) network. Since the SS7 Message Transfer Part (MTP) communication protocol and the IP communication protocol are not inherently compatible,
- 10 SS7 message packets that are to be transmitted via an IP network may be encapsulated within an IP routing envelope prior to transmission. In one embodiment, this IP encapsulation is performed by SS7/IP converter **332**. DCM **330** may utilize any one of a number of protocols in communicating call signaling messages over an IP network, including the transport adapter layer
- 15 interface (TALI) protocol, session initiation protocol (SIP), SS7 MTP2 user adaptation layer (M2UA), SS7 MTP3 user adaptation layer (M3UA), SS7 SCCP user adaptation layer (SUA), general packet radio service (GPRS) or other signaling protocols that may be transported via an IP based protocol. An exemplary protocol for communicating various types of SS7 messages in
- 20 IP packets are described in IETF RFC 3094: Tekelec's Transport Adapter Layer Interface, April 2001, the disclosure of which is incorporated by reference herein in its entirety. In an alternate embodiment of the invention, DCM **330** may implement the stream control transmission protocol (SCTP), as described in IETF RFC 2960: Stream Control Transmission Protocol,

February 2001, the disclosure of which is incorporated herein by reference in its entirety.

In general, an LCM card includes hardware and software for performing mobile subscriber location management functions and SS7 routing functions. LCM **340** shown in Figure 4 includes a signaling connection control part (SCCP) sub-module **342**, which further includes an SCCP level subsystem manager known as a signaling connection routing controller (SCRC) **344**. SCRC **344** performs SCCP and mobile application part (MAP) level discrimination processing on incoming SS7 messages. SCRC may also direct screened messages to a location register caching application (LRCA) **346**. LRCA **346** manages the processing of received signaling messages, generates new signaling messages, and administers or controls access to a visitor location cache (VLC) **350** and a home location cache (HLC) **352**. VLC **350** stores information that identifies the mobile switching center (MSC) and visitor location register (VLR) nodes in a network that are currently supporting or have previously supported a given mobile subscriber. An exemplary VLC data structure is presented below in Table 1. As indicated in Table 1, VLC **350** may have one or more records, each of which includes a mobile subscriber identifier, such as a mobile subscriber ISDN (MSISDN) or international mobile subscriber identity (IMSI) number. Other functionally equivalent mobile subscriber identifiers, such as an electronic mail address (e.g., JohnSmith@Tekelec.com) or an Internet protocol address (e.g., 101.20.10.15) may also be used as a mobile subscriber identifier in VLC **350** according to an embodiment of the present invention. The sample VLC data structure shown below also includes a timestamp field that specifies the time

and date of a given record or entry in the database, a VLR identifier field that identifies a serving VLR, and a MSC identifier that identifies a serving MSC.

Table 1: Sample Visitor Location Cache Structure

Mobile Subscriber Identifier	Timestamp	VLR Identifier	MSC Identifier
9193457018	07-01-01 11:21.01	7075551000	7075552005
2024453045	07-01-01 11:15.23	7075551008	7075552001
7074679302	07-01-01 11:09.56	7075551008	7075552001
7074679302	07-01-01 10:27.41	7075551003	7075552007

A VLR identifier may be a point code and subsystem number, a global title address, an Internet protocol network address, a uniform resource locator, etc. Similar identifier formats may also be associated with the above mentioned MSC identifier field. In an alternate embodiment, VLC database

350 may store multiple VLR and MSC identifiers for each database entry.

HLC **352** stores information associated with a mobile subscriber that is typically requested by and/or provided to VLR nodes in a network. In one embodiment, HLC **352** may store some or all of the information contained in a MAP *InsertSubscriberData* signaling message. An example of such information is presented below in Table 2. A complete description of the content of a MAP *InsertSubscriberData* message can be found in *ETSI TS 100 974 V7.6.0 (2000-09) Digital Cellular Telecommunications System (Phase 2+); Mobile Application Part (MAP) Specification (3GPP TS 09.02 version 7.6.0 Release 1998)*, the disclosure of which is incorporated herein by reference in its entirety. As indicated in the sample data structure shown in Table 2, an HLC may also include a timestamp that is associated with each record or entry and an HLR identifier.

Table 2: Sample Home Location Cache Structure

Mobile Subscriber Identifier	Time Stamp	Subscriber Status	HLR Identifier	SS Data List
9193457018	07-01-01 11:21.01	Service Granted	9195551313	CW ...
2024453045	07-01-01 11:15.23	Service Granted	2025551414	MPTY ...
7074679302	07-01-01 11:09.56	Service Granted	7075556464	CNAP ...
7036559765	07-01-01 10:27.41	Service Granted	7035554848	CNAP ...

An HLR identifier may be a point code and subsystem number, a global title address, an Internet protocol network address, a uniform resource locator, etc. In an alternate embodiment, HLC 352 may store multiple HLR identifiers for each database entry. The HLC database structure presented in Table 2 is merely illustrative of one type of information maintained by an HLC according to an embodiment of the present invention. In practice, complete or partial copies of received MAP *InsertSubscriberData* (or functionally equivalent) messages may be stored within an HLC, which employs a significantly more complex data structure than that shown in Table 2.

Returning to Figure 4, SCRC 344 further includes and controls access to a global title translation (GTT) module 354. In general terms, global title translation is a process where an identifier, which is not a valid network address, contained in a signaling message is used to obtain a valid network address that is suitable for routing the message through a signaling network. The valid network address may represent the final destination of the signaling message or the address of an intermediate network node, which will in turn be required to perform global title translation in order to continue routing of the

message. Since GTT processing is well known to those skilled in the art of SS7 network design and operation, particularly those skilled in the art of signal transfer point design and operation, a detailed discussion of GTT processing is not presented herein. It should suffice to state that outbound
5 messages that require intermediate or final global title translation during the course of MMR routing operations may be processed by GTT module **354**.

As discussed above, LRCA **346** manages signaling transactions, which may include receiving, processing, modifying, terminating, and in generating new signaling messages. Signaling transactions may include transactions
10 related to MAP or other mobility management messages, such as *UpdateLocation*, *UpdateGPRSLocation*, *InsertSubscriberData*, *DeleteSubscriberData*, *CancelLocation*, *ProvideRoamingNumber*, *SendAuthenticationInfo*, *RegisterSS*, *SendRoutingInfo*, *FailureReport*, *ReadyForShortMessage*, *ForwardShortMessage*, *DeliveryReport*,
15 *InformShortMessageDeliveryFailure*, *PurgeMobileSubscriber*, *Reset*, *RestoreData*, *ObtainMSCNumber*, and *SendRoutingInfoForLCS* messages. The ability to terminate and generate these mobility management messages in an STP or IP/SS7 signaling gateway is an important aspect of the present invention, since STPs and SGs conventionally perform only routing and GTT
20 functions and typically do not process MAP and other application level information. Message packets leaving SCRC **344** are received and further processed by a routing module **348**. Routing module **348** is responsible for the routing outbound message packets from LCM **340** to an appropriate communication module (e.g., LIM, DCM) for transmission into a signaling
25 network. Such routing may be performed using SS7 routing tables that map

SS7 destination point codes to the processor or card associated with an outbound signaling link. For example, routing module **348** may extract a destination point code value from an outbound message, perform a lookup in its routing tables, obtain an address (e.g., an IMT bus address) for the card
5 associated with an outbound signaling link over which the message is to be transmitted, and forward the message to the appropriate card via IMT bus **304**. Thus, LCM **340** performs both location management and conventional SS7 routing functions.

Because MMR node **300** performs SS7 and IP routing functions and
10 location management functions, MMR node **300** can replace an STP or SS7/IP gateway without requiring a new SS7 point code or an IP address. For example, MMR node **300** may assume the point code of the replaced node. In another embodiment, LCM **340** may be added as an upgrade to an existing STP or SS7/IP gateway, which would not require assignment of a
15 new point code. Thus, one advantage of MMR node **300** is increased functionality without increasing the number of network nodes or using additional network addresses. LCM **340** may be coupled to an external provisioning application platform (EPAP) subsystem **360** via an Ethernet connection. EPAP subsystem **360** is responsible for administration and
20 maintenance of the GTT database accessed by GTT module **354** and may also provide administrative access to VLC **350** and HLC **352**.

Mobility Management Routing Node Operation

Before beginning a discussion of MMR node operation, it should again
25 be noted that one object of the present invention includes minimizing mobile

signaling message traffic between a visited mobile network and a mobile subscriber's home network. Such inter-network signaling typically involves communication and the exchange of information between a home location register in a mobile subscriber's home network and one or more visitor location registers in a network visited by the mobile subscriber. As such, an MMR node residing in a visited network may temporarily store or cache information that is typically accessed via queries to a mobile subscriber's home network, and, as such, minimize the number of queries that must be made to home the subscriber's network from remote networks. Information related to a mobile subscriber's location within a visited network are also maintained by the MMR node in order to facilitate the efficient processing and routing of inbound signaling messages arriving from the subscriber's home network.

The present invention is not limited to the location update transactions presented below. An MMR node according to the present invention may be used to reduce inter-network traffic for any suitable transaction related to HLR ⇔ VLR communication (e.g. MAP_DELETE_SUBSCRIBER_INFO, MAP_PURGE_MS, etc), including those described in the above-referenced GLR specification. Furthermore, an MMR node of the present invention is particularly well suited to provide such location register caching functionality as a result of the STP or STP-like processing capabilities that may be included in an MMR routing node, such as MTP routing, gateway screening, global title translation, etc.

In any event, the functional block diagram of MMR node **300** shown in Figure 4 may be used in combination with the network diagram presented in

Figure 5 to illustrate the operational aspects of the present invention. In Figure 5, a mobile subscriber's home network is indicated by reference numeral **100** and a visited network is indicated by reference numeral **110**. As such, home network **100**, that is, the network to which the roaming mobile subscriber **126** belongs, includes a gateway mobile switching center **106**, an Internet protocol capable signaling gateway **108**, and a home location register **104**. HLR **104** stores subscriber information associated with the mobile subscriber **126**. Visited network **110** includes a GMSC **112**, an MSC **114**, an associated VLR **116**, an MSC node **120**, an associated VLR **122**, and an MMR **300**. SG **108** and MMR **300** may communicate with each other via the above-referenced TALI or SCTP protocols. In the illustrated example, SG **108** and MMR node **300** may communicate with other nodes via standard SS7 protocols. In an alternate embodiment, MMR node **300** may communicate with home network **100** via standard SS7 protocols. In such an embodiment, SG **108** may be replaced by an STP.

Initial UpdateLocation Processing

The first example of MMR routing node operation involves a relatively common aspect of mobile location management related signaling, which is a location update transaction. In a GSM network environment, a location update transaction involves a mobile application part (MAP) *UpdateLocation* signaling message. A detailed discussion of MAP *UpdateLocation* messages and their structure can be found in the above-referenced European Telecommunication Standards Institute (ETSI) MAP technical specification.

In a general packet radio service (GPRS) network environment, a functionally

similar UpdateGPRSLocation signaling message is utilized and would be processed in a similar manner by an MMR routing node of the present invention.

In the case of location update transactions in a mobile communications network, MMR processing can be divided into two scenarios. The first scenario involves the initial or first location update transaction associated with a particular mobile subscriber in a network served by an MMR routing node. In the example shown in Figures 5 and 6, this first scenario corresponds to a location update transaction initiated by VLR **116** when visiting mobile subscriber **126** first roams into network **110**. The second scenario involves any location update transactions associated with the mobile subscriber that follow the first transaction. Again, in the context of the example illustrated in Figure 5, the second scenario corresponds to a location update transaction initiated by VLR **122** after the first location update transaction initiated by VLR **116**. In this case, the second location update transaction may be triggered as mobile subscriber **126** roams from the coverage area of MSC **114** to the coverage area of MSC **120**.

In both scenarios discussed above, the location update transaction is initiated by a VLR. As such, communication of the MAP *UpdateLocation* signaling message from a VLR to the MMR routing node may occur either through direct addressing of the *UpdateLocation* message to the MMR node **300** or through an indirect addressing scheme. By indirect addressing, it is meant that MMR node **300** may intercept, process, terminate and respond to *UpdateLocation* messages that are not addressed directly to a network

address of MMR **300**. Both operational alternatives are described in the examples that follow.

With regard to direct addressing, an *UpdateLocation* message may be MTP addressed to an SS7 network point code and subsystem number that corresponds to the internal location register caching application of MMR node **300**. That is, in one embodiment, MMR node **300** may receive such a direct addressed *UpdateLocation* message and use the point code and subsystem address information to determine that the message requires internal LRCA processing. Such a direct addressing scheme may be realized by requiring that all VLR nodes in a network served by an MMR node address all *UpdateLocation* signaling messages to the SS7 point code and appropriate subsystem of the MMR node. In a similar manner, VLRs in the network could address all *UpdateLocation* signaling messages to the SS7 point code of a node capable of performing global title translation (e.g., an STP, an SG, or a GTT-service control point) and mark the message as requiring global title translation. In one embodiment, an MMR node may provide the STP-like GTT functionality and perform GTT processing on a received message, in addition to determining that a received message requires internal LRCA processing. Again, such message routing schemes may be achieved within the context of an SS7 network by addressing all *UpdateLocation* messages directly to the point code and subsystem of the MMR node and marking the message (i.e., routing indicator) as "route-on-subsystem," or by addressing all messages using a global title address that is indicative of the MMR node and marking the message (i.e., routing indicator) as "route-on-GT." Once again, an MMR may intercept and process mobility management messages

that are not addressed to a point code and subsystem associated with the MMR.

Referring to Figure 6, in line 1, when a mobile subscriber first moves into an area served by MSC **114**, the mobile subscriber's handset registers with VLR **116**. VLR **116** generates an *UpdateLocation* message in response to the registration. In this example, VLR **116** addresses the *UpdateLocation* message to the point code and subsystem number of the MMR node **300** with the routing indicator (RI) in the message set to "route-on-SSN."

In line 2, VLR **116** sends the MAP *UpdateLocation* message to MMR node **300**. Referring again to Figure 4, the message is received within MMR node **300**, the message may be received by LIM **308**. SS7 MTP Level 1 and 2 processing is performed on the incoming signaling message packet by the MTP Level 1 and 2 module **310**. With MTP Level 1 and 2 processing complete, the signaling message packet is temporarily buffered in the I/O queue **312** before being passed up the stack to the MTP Level 3 discrimination module **314**. Discrimination module **314** examines the signaling message packet and determines that the packet is addressed to a point code and subsystem associated with the MMR node and that the message includes a signaling connection control part (SCCP) component (i.e., service indicator value of 3). As such, the packet is subsequently passed to the distribution module **316** for distribution to location caching module **340**. The signaling message is placed on high speed IMT bus **304** and sent to LCM **340**. More detailed discrimination may be necessary to determine the particular type of SCCP processing required. This additional

discrimination may be performed at LIM **308** or at LCM **340**. In this example, the additional discrimination is performed at LCM **340**.

With regard to indirect addressing and message discrimination, in one such an embodiment of the present invention, discrimination processing by discrimination module **316** would not include examining the destination point code and subsystem parameters contained in a received signaling message. Instead, HMDC **316** may be adapted to discriminate based simply on the service indicator value, while additional SCCP/MAP discrimination is again performed at an LCM card.

After being identified as requiring further SCCP processing, the *UpdateLocation* signaling message is received by LCM **340** and passed to SCCP module **342** where message verification and further discrimination processing are performed. Such additional discrimination processing may include examination of an SCCP message type field within the message.

Within SCCP module **342**, the message packet is passed to SCRC **344**. SCRC **344** decodes and examines information contained within the signaling message in order to determine how the message should be processed. Information examined by SCRC **344** may include the SCCP calling party address (CgPA) and SCCP called party address (CdPA) fields of the received signaling message. A subsystem (SSN) parameter within the CdPA field may be examined to further identify the purpose of the message. For example, a CdPA:SSN value of 6 indicates that the message is intended for a HLR processing, a value of 7 indicates VLR processing, a value of 8 indicates MSC processing, a value of 5 indicates mobile application part (MAP) related processing, etc. In the context of the present example, SCRC **344** may

further examine the message contents (e.g., a MAP message type parameter) so as to identify the message as being a MAP *UpdateLocation* message.

Having determined the received message to be an *UpdateLocation* message, a mobile subscriber identification number (e.g., MSISDN, IMSI, etc.) encoded within the *UpdateLocation* message is subsequently extracted and conditioned, as necessary. The mobile subscriber identification number is stored within the CdPA field in a field commonly referred to as the global title digits (GTD) parameter. In this example, the GTD parameter has a value of 9193457018 and it is further assumed that no conditioning of this number is required.

However, with regard to number conditioning, such processing may be necessary to ensure that the IMSI or MSISDN is compatible with the format of the key field data stored in VLC 350 and HLC 352. Number conditioning operations may include pre-pending extra digits to a mobile subscriber identification number contained within a signaling message packet to force the number to conform to an international format. Conversion of a mobile subscriber identification number from one numbering standard to another may also be performed. For instance, the mobile subscriber identification number associated with an incoming signaling message packet may be converted from a first industry standard format, such as E.214, to a second industry standard format, such as E.212, prior to database lookup operations. Such mobile subscriber identification number conditioning services may be necessary only in the case that the format of the incoming message mobile subscriber identification number is not consistent with the corresponding key field data format in the location register caching databases.

In any event, the MSISDN or IMSI extracted from the *UpdateLocation* message is used to perform a lookup in HLC **352**. Since mobile subscriber **126** (i.e., MSISDN = 9193457018) has not been previously registered in the visited network **110**, HLC **352** does not contain an entry associated with the mobile subscriber, and consequently the lookup does not return a match. From this, the MMR knows that communication with the HLR is still required for this message (as opposed to the MMR being able to respond on behalf of the HLR).

A new entry for mobile subscriber **126** is next inserted into VLC **350**.

As indicated in Table 1 above, this new entry includes the mobile subscriber identification number, a timestamp, as well as serving VLR and serving MSC identification information extracted from the *UpdateLocation* message. Once the serving VLR and serving MSC information has been recorded in VLC **350**, these parameters may be modified in the *UpdateLocation* message.

That is, the serving VLR and serving MSC parameters may be changed to identifiers associated with MMR node **300**. For example, an MMR node of the present invention modify the contents of a received message so as to reflect a pseudo-VLR identifier, MSC identifier, or HLR identifier that has been previously assigned to the MMR node. In such a case, subsequent communications from the mobile subscriber's HLR will be directed to MMR node **300**. In an alternate embodiment, the serving VLR and serving MSC parameters need not be modified. In such a case, MMR node **300** may transparently intercept and examine all mobility management type signaling messages entering the visited network from a remote or foreign network. As

such, explicit direction of subsequent signaling messages to the MMR node is not essential to the operation of the present invention.

In any event, once the VLC and HLC updates are complete, the *UpdateLocation* message is directed to GTT module **354**, where global title translation processing is performed on the *UpdateLocation* message. The result of such GTT processing is a destination address to which the *UpdateLocation* message can be forwarded for delivery to the mobile subscriber's HLR.

This initial *UpdateLocation* message is GTT processed and routed from LCM **340** via the internal routing module **348** to DCM **330**. DCM **330** encapsulates the *UpdateLocation* message within a transport adapter layer interface (TALI) packet, and applies an appropriate Internet protocol (IP) header.

Referring again to Figure 6, in line 3, MMR node **300** transmits the packet via an IP network to SG **108** residing in the mobile subscriber's home network **100**. SG **108** receives the TALI packet and extracts the encapsulated *UpdateLocation* message. SG node **108** routes the *UpdateLocation* message to HLR **104** where the message is processed.

In response to the receipt of the *UpdateLocation* message, HLR **104** generates and returns a MAP *InsertSubscriberData* message, which includes subscriber specific information associated with the mobile subscriber **126**. The *InsertSubscriberData* message may be addressed via the serving VLR and/or serving MSC identifiers to MMR node **300**. However, as discussed above, such direct addressing to the MMR node is not essential, because

MMR node **300** may be programmed to intercept and examine all incoming mobility management type messages, regardless of the destination address.

In line 4, the *InsertSubscriberData* message is routed from home network **100** back to the visited network **110**, where it is received by MMR node **300**. Upon receipt by MMR node **300**, the message is examined and internally routed to LCM **340** in a manner similar to that described previously with regard to the original *UpdateLocation* message processing. The *InsertSubscriberData* message is internally directed to the location register caching application **346** (LRCA), where a copy of some or all of the information in the message is stored in HLC **352**, including the mobile subscriber identification number and a timestamp.

If the serving VLR and serving MSC identifiers reflect values associated with MMR node **300**, LRCA **346** may reset these values to the original serving VLR and MSC entity identifiers using the serving VLR and MSC identifier information previously stored in the VLC database **350**. If the serving VLR and serving MSC identifiers as sent by HLR **104** are correct, then the identifiers are not modified by LRCA **346**. In either case, the *InsertSubscriberData* message is subsequently directed to GTT module **354** for address translation processing, and routing to the serving VLR **116** via routing module **348** and LIM **308** in a manner similar to that previously described (line 5).

Since the *UpdateLocation* and *InsertSubscriberData* transactions require confirmation service, serving VLR **116**, upon receipt and processing of the *InsertSubscriberData* message, will generate a confirming *InsertSubscriberData_Ack* message. In the case of an initial *UpdateLocation*

transaction, this message may be routed through to HLR **104** without requiring MMR processing (lines 6 and 7), because it will be addressed to the HLR and the MMR will know that the message should not trigger the LCRA.

In a similar manner, upon receipt and processing of the

5 *InsertSubscriberData_Ack* message, HLR **104** will generate a confirming *UpdateLocation_Ack* message and forward the *UpdateLocation_Ack* message to MMR node **300** (line 8). Once again, since the MMR is not terminating the initial *UpdateLocation* transaction, this message may be routed through to VLR **116** without requiring MMR processing (line 9). The
10 example of confirmation and acknowledgment messaging illustrated in Figure 6 assumes that successful *UpdateLocation* and *InsertSubscriberData* transactions have occurred. In the event of an unsuccessful transaction attempt, the HLR and VLR nodes may generate various error messages. However, because in the case of the initial *UpdateLocation* transaction, MMR
15 node **300** is not terminating the transaction, such error messages would not be of particular significance with regard to the operation of MMR node **300**.

Not shown in Figure 6 is the subsequent CANCEL_LOCATION message, which HLR **104** sends to the previous VLR once the location update procedure with the new VLR **116** is successfully completed.

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Subsequent Location Update Processing

The operation and benefits of an MMR node of the present invention will now be explained with regard to location update transactions that occur after the initial location update transaction. Figure 7 is a message flow
25 diagram illustrating a location update transaction after MMR node **300** has

cached location information regarding a mobile subscriber from a previous location update transaction. As illustrated in the message flow diagram of Figure 7, once the HLR data associated with mobile subscriber **126** is cached in MMR node **300**, the forwarding of *UpdateLocation* queries generated by VLR nodes within the visited network **110** to the mobile subscriber's home network **100** is not necessary. In the case of subsequent transactions, these *UpdateLocation* and *InsertSubscriberData* transactions are terminated or originated by MMR node **300**. To illustrate this point, a typical subsequent *UpdateLocation* transaction will now be described.

When mobile subscriber **126** roams from the service area of MSC **114**/VLR **116** and enters the service area of MSC **120**/VLR **122**, the mobile subscriber's handset sends a registration message to MSC **120**. In response, MSC **120** sends a registration message to VLR **122** (line 1). As a consequence of such registration activity, an *UpdateLocation* transaction will be initiated by new serving VLR **122**. As described above, this *UpdateLocation* message may be addressed to MMR node **300**, or the message may be intercepted during routing operations at MMR node **300**. In line 3, the Update Location message is forwarded to MMR node **300**. Within MMR **300**, the *UpdateLocation* message is directed to location register caching application **346** (LRCA), where a lookup is performed in HLC **352** using a mobile subscriber identifier (e.g., MSISDN, IMSI, etc.) extracted from the message. In this case, a lookup in the HLC **352** returns the entry associated with mobile subscriber **126** that was previously inserted during the initial transaction. Because the HLC has a record of this subscriber with a valid timestamp, the MMR knows it does not need to communicate with the

HLR in order to complete this transaction. Rather, the MMR can act on behalf of the HLR in communicating with the VLR. The HLR would still communicate with the MMR for messages it receives concerning this subscriber. In this way, the MMR is also acting on behalf of the VLR. As
5 such, LRCA **346** extracts the mobile subscriber's information from HLC **352** and generates an *InsertSubscriberData* message containing some or all of the mobile subscriber's data that was stored therein. The *InsertSubscriberData* message is then passed to GTT module **354** for address translation processing and routing to the new serving VLR **122** via
10 routing module **348** and LIM **308** (line 3).

In a manner similar to that described above, a new entry for the mobile subscriber **126** is next inserted into VLC **350**. As indicated in Table 1 above, this new entry includes the mobile subscriber identification number, a timestamp, as well as serving VLR and serving MSC identification information
15 extracted from the *UpdateLocation* message. Because this is the second *UpdateLocation* message received for the mobile subscriber, an entry for mobile subscriber **126** already exists in VLC **350**. This existing VLC entry includes a different timestamp and identifier information associated with the previously serving MSC **114** and VLR **116**. Referring again to Figure 7, the
20 confirmed nature of the *UpdateLocation* and *InsertSubscriberData* transactions requires that the new serving VLR **122** respond to MMR **300** with an *InsertSubscriberData_Ack* (or appropriate error) message (line 4). Upon receipt of the *InsertSubscriberData_Ack* message LRCA **346** may complete the *UpdateLocation* transaction via the formulation of an
25 *UpdateLocation_Ack* (or appropriate error) message, which is routed to the

new serving VLR **122** (line 5). In one embodiment, MMR node **300** may then generate a MAP *CancelLocation* message using the information stored in the old or existing entry and forward the *CancelLocation* message to the previous serving VLR **116**. This message informs the previous VLR **116** to purge the subscriber **126** from its database since it is now registered with a new VLR. This action is normally performed by the HLR, but in this case it is performed by the MMR on the HLR's behalf. However, other embodiments of the present invention may postpone the sending of a *CancelLocation* message and allow the old or existing entry to remain in the VLC even after a new serving VLR in the visited network has been identified. The reasoning and advantage of postponing the deletion of the subscriber data from the previous VLR is that if a subscriber is frequently switching back and forth between two VLR areas, then both VLRs can retain the information and do not have to initiate new location update procedures every time the roaming subscriber returns. For instance, if a subscriber is in the area serviced by VLR **116** and crosses into VLR **122**'s area, then ten minutes later crosses back into VLR **116**'s area, then five minutes later crosses back into VLR **122**'s area, this would normally require four separate full location update procedures. However, if the MMR uses the information it intercepted from the initial update to VLR **116** to perform the first update to VLR **122**, and does not tell VLR **116** to cancel the subscriber's information, then when the subscriber crosses back into VLR **116**'s area, the full location update procedure is not required since VLR **116** still contains the subscriber's information. Rather, a "condensed" location update procedure is used that eliminates some of the messages normally required. This "condensed" procedure is described in

detail in 3G TS 23.116 v3.0.0, Technical Specification Group Core Network; Super-Charger Technical Realisation; Stage 2 (Release 99). Likewise, since VLR **122** is not told to purge the subscriber's information, then a full location update procedure is not required when the subscriber returns to its area for the second time. Again, a "condensed" procedure is used that further reduces the signaling. Note that the HLR is not involved in any of the above transactions. If a message comes to the MMR from the HLR (in this case, the MMR is acting on behalf of the VLR), the MMR uses the timestamps associated with the data it receives as part of the "condensed" procedure to determine the valid VLR area that the mobile is currently associated with and passes this information to the HLR on behalf of the VLR. Such postponement may be based on a time interval (e.g., a statistically determined time interval, fixed time interval, etc.), or may rely on the receipt of a *CancelLocation* message from the mobile subscriber's HLR **104**, when the subscriber goes to a new network not associated with MMR **300**. Note the new network may or may not have MMR functionality. In such scenarios, one embodiment of an MMR node of the present invention may generate and distribute copies of a *CancelLocation* message to multiple VLR nodes in the visited network **110**, as illustrated in Figures 8 and 9. That is, when mobile subscriber **126** roams out of visited network **110** and into another visited network **140**, MS **126** registers the mobile subscriber with VLR **146** (line 1), and the new serving VLR **146** triggers an *UpdateLocation*. This *UpdateLocation* message will be routed to the mobile subscriber's HLR **104** (line 2) and the appropriate acknowledgement and *InsertSubscriberData* messages may be exchanged (lines 3-5). After processing the

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UpdateLocation message, HLR **104** will generate a *CancelLocation* message directed to the last known location (which in this case is MMR **300**). This *CancelLocation* message is routed to the former visited network **110** and will be received by MMR node **300** (line 6). In response to the receipt of this

5 *CancelLocation* message LRCA **346** may determine which VLRs in the network **110** have served mobile subscriber **126** using data stored in the VLC **350** and not yet received a cancel location. Once the former serving VLR information is extracted from VLC **350**, copies of the received *CancelLocation* message may be generated and sent to all concerned VLR nodes (lines 7

10 and 8). Upon completion of such processing, entries associated with mobile subscriber **126** may be purged from both VLC **350** and HLC **352**.

Mobile Terminated Call Processing

Another relatively common mobility management type transaction that

15 is supported by a MMR routing node of the present invention involves a transaction sequence related to mobile terminated calls. Figure 10 is a message flow diagram illustrating mobile terminated call processing involving an MMR node according to an embodiment of the present invention. In particular, during the course of call setup to a mobile subscriber roaming in

20 visited network **110**, the mobile subscriber's HLR **104** receives a routing information query (e.g., a MAP send routing information query message) from a gateway MSC **106** (or functionally equivalent node) that requires information related to the location of the mobile subscriber **126** (line 1). From the *UpdateLocation* transactions described above, the mobile subscriber's

25 HLR **104** contains information that identifies the mobile subscriber **126** as

being located within network **110**. As such, HLR **104** may generate a MAP *ProvideRoamingNumber* message and subsequently route this message to network **110** (line 2). This message is normally destined for the VLR currently associated with the subscriber. However, MMR node **300** may

5 receive the MAP *ProvideRoamingNumber* message and direct the message to the location register caching application **346** (LRCA) in a manner similar to that described above. LRCA **346** performs a lookup in VLC **350** using a mobile subscriber identifier (e.g., MSISDN, IMSI, etc.) contained in the *ProvideRoamingNumber* message and locates the most current entry based

10 on the timestamp extracted from the UpdateLocation messages, as described above. With the most current entry located, the serving MSC and VLR information contained therein is used to ensure that the message is routed to the correct MSC and VLR. As such, the modified *ProvideRoamingNumber* message is routed from MMR **300** in a manner

15 similar to that previously described (i.e., GTT processing is performed as necessary). MMR node **300** may relay the ensuing *ProvideRoamingNumber_Ack* (or error) message back to HLR **104**, so that call setup operations may continue (line 3). Because MMR node **300** caches subscriber location information and responds on behalf of a VLR, network

20 traffic and mobile terminated call setup time are reduced.

Mated MMR Node Synchronization

Another feature of the MMR embodiments described herein involves the issue of a mated pair deployment of MMR routing nodes in a mobile

25 communications network. SS7 STP and SG nodes are most often deployed

in mated pairs for load-sharing, reliability, and redundancy. As such, MMR nodes of the present invention may also be deployed in mated pairs for similar reasons. While the deployment of an MMR node of the present invention in mated pairs does not impact the core location register caching functionality described herein, some degree of synchronization or consistency must be maintained between the home location register and visitor location register caches residing in each of the mated MMR nodes. As such, MMR nodes deployed in mated pairs communicate information for maintaining database synchronization via a shared EPAP database administration system, such as that shown in Figure 4. In an alternate embodiment, mated MMR nodes communicate information for maintaining database synchronization via a cross or "C" link type signaling connection that connects the two nodes.

Synchronization of the home register and visitor location register caches may occur by having one MMR of a mated pair send a copy of VLC and HLC database updates based on received signaling messages to its mate. The node that receives the database update from its mate may update its local HLC and VLC databases based on the information in the database update. If the timestamp in a received database update is less than a current timestamp in the receiving MMR's HLC or VLC, the receiving HLC or VLC may refuse to perform the update and send a database update to its mate. In this manner, synchronization between HLCs and VLCs of mated MMR nodes can be automatically maintained.

As described above, an MMR node according to embodiments of the present invention caches mobile subscriber information, performs both HLR

and VLR functions, and performs SS7 routing functions. Such functions reduce the need for location update messages to be routed to the mobile subscriber's home network each time the mobile subscriber enters an area served by a new MSC within the same visited network. In addition, MMR node 300 may generate location cancellation messages to purge VLRs or HLRs of outdated location information. During mobile terminated call setup, MMR node 300 may respond on behalf of a VLR in response to ProvideRoamingNumber query messages. Thus, an MMR node according to the present invention reduces call setup time, decreases mobility management network traffic, and provides increased functionality over conventional STP and SS7/IP gateway nodes.

It will be understood that various details of the invention may be changed without departing from the scope of the invention. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation—the invention being defined by the claims.